CELESTIAL CHEMISTRY *

II.

WE have now gone through as briefly as I can manage to do it, the principal points in chemistry and the principal points in spectrum analysis with which we have to deal when we are dealing with the chemical substances of our own planet. You see the point of inquiry is the chemical and spectroscopic study of the differences between atoms and molecules. We have now to apply these two lines of thought to a consideration of what I have called Celestial Chemistry.

In the first place, how is the study of Celestial Chemistry carried on? To answer this question I will give you an idea of the way in which the spectroscope is added to the telescope. We, of course, require a spectroscope in order to bring into play refraction or diffraction, and we equally, of course, require a telescope in order to collect the light which comes to us from the various light sources which are to be found in the sky. You now see a photograph of what is technically called the eye-piece end of the most perfect and most powerful telescope in the world, which I am proud to say is in England. It is the telescope belonging to Mr. Newall of Gateshead. We see the principal telescope and the various finders, which enable the observer to find the most delicate object which shines in the sky.

You will get an idea of the enormous quantity of light collected by this instrument, when I tell you that the diameter of the pupil of the eye is less than a quarter of an inch, and that the diameter of the object-glass of this telescope is 25 inches, and that the quantity of light utilised depends upon the squares of the diameters. Of course, when we have to deal with feeble celestial objects lying at an immense distance from us, and which give but little light, it would be absolutely impossible to use the prism with any effect unless in the first instance we thus collected a large amount of light to work with.

Now then, having our spectroscope attached to our telescope in the way indicated, to what must we turn our attention? You will see in a moment that it is useless to consider such a body as the moon. I say useless, of course bearing in mind that we are here dealing with chemical considerations, because the light which we get from the moon is simply sunshine second hand, and the moon has no atmosphere. The same remark applies to a certain extent when we deal with the planets, because they also, as you know, are lit up like the moon by the sun, but they have atmospheres, and much is to be learned from them in this way. What we have to do in the main to get a just general outline, in order to study this Celestial Chemistry is, to confine our attention to those bodies which shine by their own light. And if you think the matter over for a minute you will see that there are two distinct classes of such bodies. In the first place there are the *Nebulæ*, and *Comets*, and *Meteors*, which shine by their own light. And again, there are the *sun* and the *fixed stars*, which shine also by their own light; but with this important difference, that while we get the initial light radiated by a nebula, a comet, or meteor, the light which we get from a star is not the initial light, but a difference light; a great deal of the light radiated having been stopped by the atmosphere of the star. So that in the case of a sun, by which of course I mean a star—our sun being merely the star which is nearest to us—although it shines by its own light, we get a difference light while we get what we may call the total light from the first class.

And here let me add that it is the chemical composition of the atmosphere of the star which thus stops the light which we can study. If the stars had no atmospheres there could be no star chemistry, because their spectra would be continuous, and in that case neither qualitative nor quantitative spectrum analysis would be possible.

We deal then with radiation in objects of the first class and with absorption in objects of the second class.

Let us commence our study of those objects which shine by their own light by the study of the comets and the meteors. It is unfortunate that since the more general use of the spectroscope, no large comet has made its appearance, but still some small ones have been observed.

There is a spectrum which in the main is common to a great many of the compounds of carbon; and here I may parenthetically remark that carbon is, of the sixty-three elements to which I have referred, the only element which with the electric power that we can employ in the arc presents us with the distinct appearance of a compound spectrum. Side by side with this generic spectrum of the compounds of carbon I will show you the spectrum of the head of a comet which was observed some years ago; and I may add that several other comets have been observed since, with the indication that their spectra are to a very large extent, if not absolutely, the same; so that we may say there is a probability that, in the case of some of the comets at all events, we are dealing with a class of bodies in which a compound of carbon is concerned, or if not that, that the molecules of the comet resemble somewhat those of the chemical substances which give us such spectra.

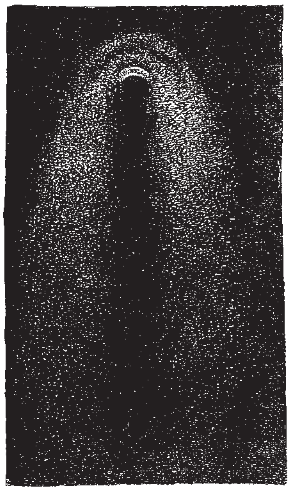

FIG. 1.—Head and Envelopes of a Comet.

Closely connected with comets by the recent hypothesis of Schiaparelli, are meteors, and falling-stars. So far as I know at present, in the case of falling stars the cometary spectrum has not been seen, but it has been noticed in several shooting-stars that the vapour of sodium is present, indicated by the double bright line in the yellow part of the spectrum. Now the meteorites are large meteors which have fallen to the

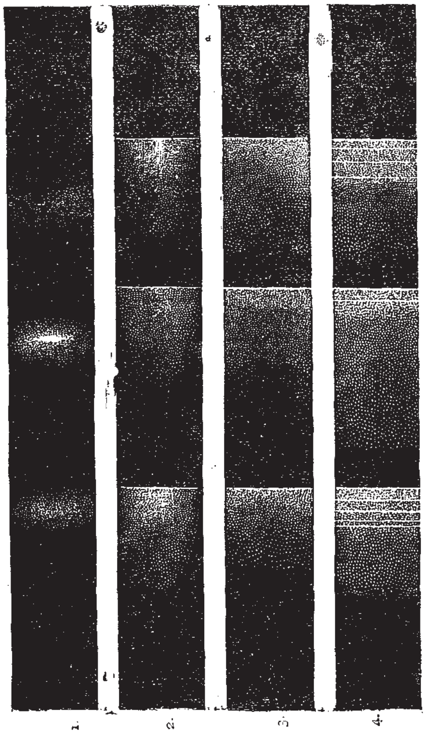

FIG. 2.—1, Spectrum of Brorsen's comet; 2, Spectrum of Winnecke's comet; 3, Spectrum of carbon in olefiant gas; 4, Spectrum of carbon in olive oil. (Huggins.)

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* Revised from short-hand notes of a Lecture delivered at the Quebec Institute, on Tuesday, December 16, 1873. Continued from p. 414.

earth, and this being so, we can chemically examine them as easily as substances which have consolidated here. These bodies may be roughly divided into iron meteorites and stone meteorites, and roughly again into meteorites which contain elementary metallic molecules, and others which contain compound molecules, that is, mixtures of metals with the metalloids.

The observations of the spectra of nebulæ we owe mainly to Mr. Huggins, a distinguished English observer, who has given very much attention to this branch of inquiry. One thing we know for certain about the nebulæ from these observations is this: we are dealing either with gases alone or with solids banging about in gases, and one of the bright lines which we observe tells us that we are dealing with hydrogen gas; so that the same method of inquiry which, applied to comets, tells us that probably in some cases we are dealing with a compound of carbon, tells us that we are chiefly dealing, in the case of nebulæ, not with a compound of carbon or with a compound of anything, but with a true element—hydrogen.

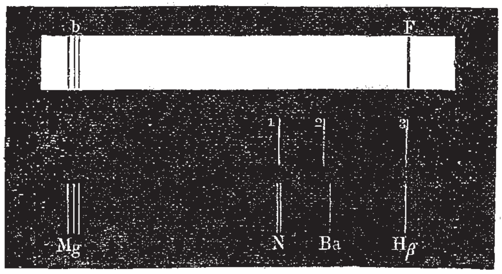

FIG. 3.—Spectrum of the nebulæ.—1, 2, 3, lines observed. Above, the solar spectrum is shown from *b* to F; below, the bright lines of magnesium, nitrogen, barium, and hydrogen, in the corresponding part of the spectrum.

That, you see, is a very great step; and a very few years ago it would have been considered presumptuous almost to think that man could ever tell what substances were building up the nebulæ which lie at such infinitely remote distances from us.

So much then for comets and meteors and nebulæ. These exhaust the bodies in space which shine by their own light, the light not being subsequently absorbed by an atmosphere through which it passes; we will now therefore pass to the class of Stars.

With regard to stars, I have a diagram to bring before you, which summarises in a convenient way a good deal of the work which has been very carefully done by Father Secchi of Rome. I shall have to refer to several other diagrams afterwards; but this, I think, is the best one to place before you in the first instance.

The spectra in the diagram are the spectra of various stars. You will at once see that there is a difference between those spectra, and you will see that there is a double difference between some of them. In the first place, you have an extreme simplicity in some cases and complication in the others. But you see, also, that the question of simplicity and complication is not the only question, that is a question merely of degree; but there is a difference in kind. For instance, you will at once acknowledge a difference in kind between the spectrum of α Herculis and Sirius.

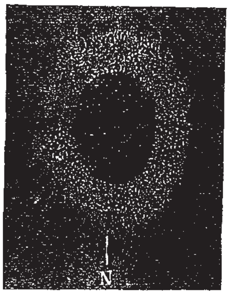

FIG. 4.—Ring nebula in Lyra, with its spectrum.

The diagram of the former, although it has been made in no laboratory, and although it deals with no metalloids or no compounds which have been got upon the earth, is as good a diagram as I can put before you to explain what I mean by the channelled structure of the spectrum of the metalloids as opposed to the line spectrum of the metals.

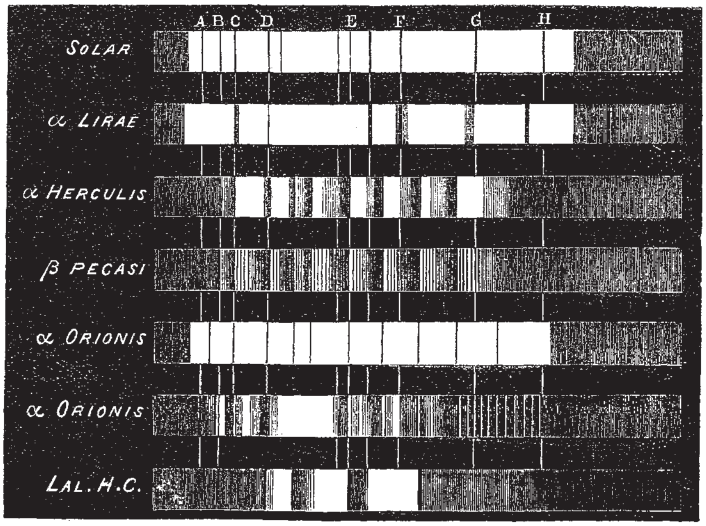

FIG. 5.—Various Stellar Spectra (Secchi).

Bearing in mind the great simplicity of the spectra of stars like α Lyræ and Sirius, and the greater complexity of the spectral lines in a star like the sun; bearing in mind, also, the difference in kind between the spectra that I have referred to, we can divide all the stars which shine in the heavens which we have already observed, into three classes. This has been done by Rutherfurd and Secchi.

Let me strengthen what I have to say by showing you rather more elaborate drawings of three stars belonging to these different classes. You will now see the importance of the considerations which I have brought before you regarding the spectra of the metals and the metalloids. There is the channelled space spectrum of the star α Herculis; there is the banded spectrum of the star α Orionis; and there is the equally banded spectrum of a star in the constellation of the Scorpion. In all these cases you will see we are dealing, not with the first class in which we have simple spectra, but with the second and third classes.

Now let me contrast on another diagram the spectra of two stars, one in the first class and the other in the second. Let us contrast the spectrum of Sirius with the spectrum of the star in Orion, to which I have already referred. In the spectrum of

Sirius observe—for this is a very important point—the extreme thickness of the lines, which are the lines due to hydrogen, and contrast the thickness of these lines and the simplicity of the spectrum with the thinness and great number of the lines in the star in Orion, and the complexity of its spectrum; and remembering that both these maps are on the same scale, let me point out that all the lines which are so thick and so obvious in the spectrum of Sirius, are altogether wanting in the spectrum of the star in Orion.

I hope I have convinced you, by the sight of these diagrams, that supposing the observations on which they are based to be true, we have in the stars which shine three perfectly different kinds of absorption of light going on in the atmospheres of those stars. We have an absorption which we may call a simple absorption, seeing that the lines are few in number; we have an absorption of the same kind, but different in degree, which we may call complicated, seeing that the lines are still lines, but that they are very much increased in number. And, again, in the third class we have an absorption of a different kind altogether; instead of having an absorption of lines we have an absorption of bands. This I shall venture to call a metalloidal absorption.

Of course if we were merely limited to the spectrum of these distant stars, in spite of the enormous skill and care which Mr. Huggins and Father Secchi have brought to bear upon this inquiry, we probably should never go very much further; but you know that the sun is, after all, our sun, merely for the reason that it is the nearest star; and therefore it is clear to you that if we observe the sun with anything like the attention that it deserves, bearing in mind its comparative nearness to us, we ought to be able to get out of the sun a great number of facts which will help us the better to understand the various appearances in the different stars.

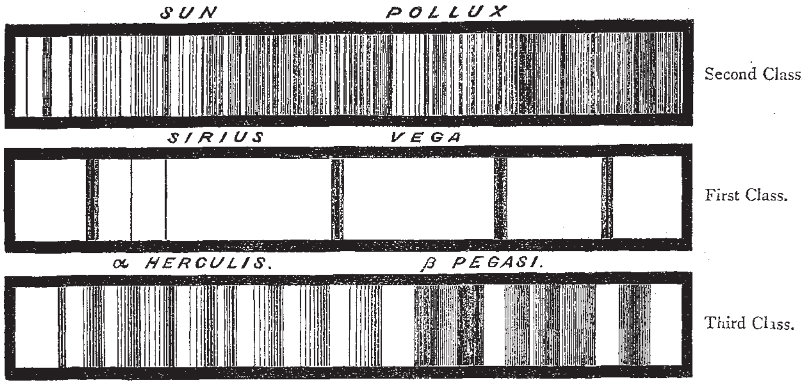

FIG. 6.—The Three Classes of Stars (Secchi).

I need not say to you that a great deal of trouble has been taken to understand the sun, to study its physical and even its chemical constitution; and if you will allow me, I will put before you two or three considerations having reference to the sun, which have a bearing of considerable importance upon Celestial Chemistry.

In the first place, let me call your attention to the sun as we see it ordinarily. We see that on the sun there are spots, and that on the limb there is a dimming; both the dimming of the limb and of the spots being due to the absorption of the sun's atmosphere which is at work, as I have already told you in the case of the stars, and which separates the stars as a class from the comets, meteors, and the nebulæ.

Next consider the sun as it is seen in an eclipse. Some of you may be surprised to learn that the sun, as we see it every day, is not by any means the whole sun, but only, so to speak, the kernel of an enormous mass of vapour extending for thousands and tens of thousands of miles around the visible sun.

Now in an eclipse, when all the sun ordinarily visible is hidden, we get indications of a very bright something extending to some little distance above the visible sun. On this point I may specially call attention to a photograph taken in the eclipse of 1870, at Syracuse, in which, outside the dark moon which is covering the sun, and therefore outside the sun, a mass of light which we know to be due to vapours surrounding the sun is indicated.

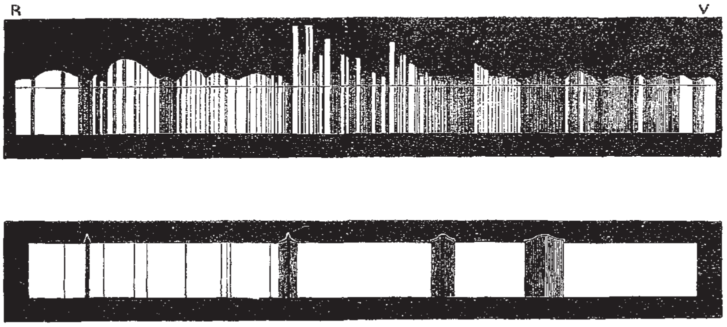

FIG. 7.—Spectra of α Orionis and Sirius (Secchi). In the spectrum of α Orionis the brightness of the spectrum is represented by the height.

In a photograph taken in India in the year 1871, under somewhat different conditions, we were fortunate enough to record a great deal more of the sun's surroundings. In this, surrounding the dark moon, we have an immense mass of something not very bright extending to a very considerable distance indeed above the visible sun.

Now, by studying these phenomena in the case of the sun, of course we are studying similar things in the case of every star; and what do we find? We find, in the case of the sun, that surrounding the visible sun there extends to a very considerable distance an atmosphere of an element that we have not here, and which is probably lighter than hydrogen. Immersed in this, and therefore extending to a smaller distance from the sun, is another envelope, which has been called the chromosphere, consisting, in the main, of hydrogen. The brightest part of this lies pretty close to the sun. This region is excessively bright—so bright, that by a certain method it can be seen without any eclipse whatever. Immersed in this hydrogen and therefore still nearer the sun there is an enormous quantity of vapours of the different elements existing in the sun, in what we may term a reversing layer, and it is to the absorption of the elements in this layer that the absorption of the sunlight, and therefore, so to speak, the creation of the spectrum of the sun, is in the main due.

I will now direct your attention to two photographs of the solar spectrum, and reminding you that the complexity of a spectrum depends upon the number of elements, and upon the pressure at which the vapours of those elements exist in the atmosphere of any star, you will gather from these photographs a pretty good idea of the extreme complexity of the sun's reversing layer to which I have referred.

In a photograph of any part of the sun's spectrum each of the lines of course has its story to tell, not only so far as the substance which is at work doing that particular part of the absorption is concerned, but also even so far as the quantity of that substance is concerned; because not only will a certain substance absorb particular waves of light, but it will absorb many waves, or few, or none at all, according to the quantity of that particular substance in the envelope surrounding the sun. Now there is a great deal of calcium in the sun, and therefore the absorption lines of the calcium are very thick, the absorption lines of the other metals which do not exist in such great quantities in the sun being very much thinner.

Having brought before you these various points connected mainly with the sun, so far as its physical constitution goes, let us consider what is the chemical constitution of the sun.

I have already told you that surrounding the sun is an envelope composed in the main of hydrogen, and of a new element, and that nearer to the sun is a region of vapours of great complexity, containing at least one new element. This region contains, besides hydrogen, and dealing with known elements, magnesium, sodium, titanium, calcium, nickel, chromium, iron, manganese, aluminum, copper, zinc, barium, cobalt, and so on, and latterly we have had reason to suppose that some six or seven new elements must be added to the list—potassium, lead, cerium, uranium, strontium, and cadmium. Further, if instead of the new "atomic weights" of the elements we take the old "combining weight" we find that the arrangement of these layers round the sun follows the vapour densities of the various substances either absolutely or very closely.

This then is the verdict of the prism with regard to the chemical constitution of the sun, the nearest star that we can get at; and I think you will acknowledge that if the prism had done nothing else it would have done good work. But I think it has done very much more, because it has enabled us not only to chronicle those things as existing in the sun, but in connection with the other facts which I have already brought before you it has enabled us to place the sun in its proper position amongst the stars. For instance, I have already called your attention to the first, second, and third classes of stars. Is the sun in the first, the second, or the third class? Does its spectrum contain few or many lines? or are there channelled spaces or bands? Its spectrum is not excessively simple; there are no channelled spaces or bands; and therefore the sun is to be placed in the second class of stars. Can we then go beyond this chronicle of facts, which I am afraid some of you may have considered rather dry?

You know that what a scientific man has to do in any research is not merely to add fact to fact, and to go blindly looking after facts irrespective of order. What he has to do after he has accumulated a certain number of facts is, to try whether it is possible to arrange them in order. If you wish to get a law out of any accumulation of facts in physics, in chemistry, or astronomy, you must first get your facts into order or you will never do it. Is there any possible order into which we can group these various facts to which I have referred? I venture to think there is.

Call to mind the three classes of stars. Is there any other physical quality tacked on to those differences? Yes. The stars with the simplest spectra are on the whole the brightest stars in the heavens; and the channelled spaced stars are on the whole the dimmest stars in the heavens. Of about 500 stars which have been already observed, over 300 are of the complicated second order or type. There are a great many bright stars of the first order, but an extremely small number, only, I think, about 27 of the third order with the channelled space spectrum. Now, if this be true, and if it be fair to assume that the star which is the brightest is on the whole the hottest, and I think it is fair to say so, if you take all other things as equal, then you come to a generalisation of this kind, that the brightest and hottest stars in the heavens have the simplest spectra, and the dimmest, reddest, coldest stars have a spectrum entirely different. If this be so, can we connect these facts? I think so. Grant these facts (and the future alone will show whether they are facts), and the thing is clear. We may group them all together by supposing that in the stars of the first and second classes there are dissociating forces at work which, from considerations which I have not time to bring before you now, we can imagine to be infinitely higher, or at least considerably higher, than any dissociating force that we can get here even with the electric spark. If you imagine in these stars an atom-severing force greater than we can obtain here, you can at once group in a working hypothesis all the facts which I have brought before you, and in a simple way; and let me add that simplicity in Science is a very great evidence of truth.

If you assume that at the highest possible temperature—here I use the word temperature for want of a better—of a star you have work done in continuation of the work done in terrestrial furnaces, that is to say, if instead of having 63 elements which we have here with our furnaces, there is a much smaller number, taking into consideration the increase of temperature, you will see at once that the brightest and hottest star in the heavens should have the simplest spectrum, because there you have the fewest elements, and that the coldest, reddest, dimmest star should have a spectrum indicating metalloids and compounds because you have there a low temperature, at which the metals do not exist except in combination. And if you think this matter over you will see that this suggestion of a higher temperature giving us a simpler condition of what we with our paltry temperatures call chemical elements, instead of making these stellar spectra complicated, difficult to recollect and to understand, puts them all in one line easily to be grasped, and a line which I venture to think is somewhat coincident with the probabilities of the case.

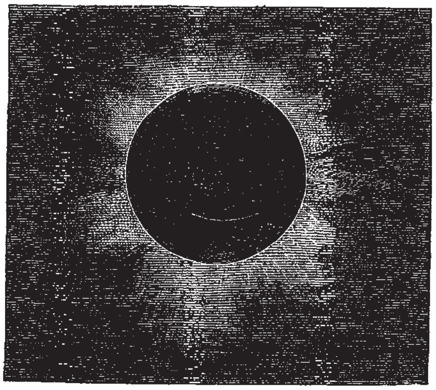

FIG. 8.—The Corona (Indian Eclipse, 1871).

Does the work stop there? Has it nothing to say to comets and meteorites? Here again it has a question to ask. The beautiful hypothesis of Schiaparelli, which is accepted by all astronomers, has made it perfectly clear that a comet is nothing more than one of an infinite number of meteors or meteorites, or whatever you like to call them, travelling in cometary orbits round the sun, and to which the showers of shooting stars are due. We know that there is a comet connected with that particular meteor swarm which gives us the November meteors, and we know that there is another comet connected with that particular meteor swarm which gives us the August meteors; and we assume that in all probability there are millions, or any enormous number that you like, of meteors, or meteorites, or shooting stars peopling a part or the whole length of that concrete orbit so to speak.

How is it then that there is only one comet amongst all that infinite number of potential meteors or meteorites? Here again I am sure that the future will enable the prism to throw an immense light, and we already have a glimmering. If, for instance, you assume that out of a star of the second class, in the reversing layer of which there are no metalloids, portions of the atmosphere are, by forces which we know to be at work, thrown bodily from the sphere of the star's attraction into space, those vapours on being cooled would give us very much the same kind of chemical composition that we get in the well-known masses called iron meteorites, composed principally of iron and nickel. While on the other hand, in the case of stars of the third class, in which it seems excessively probable that we have both metalloids and compounds, and very little pure metal, that is to say, metal not in combination, in the reversing layer, we have also the large class of silicate meteorites, the origin of which is possibly due to such stars in exactly the same way as the origin of the iron meteorites would be due to stars of the second class.

If this be so, then it would seem that a comet is simply a meteorite which contains something which is volatile at a very low temperature. Amongst the vapours known to chemists, which are volatile at the lowest temperature, are the hydrocarbons. I have already pointed out to you that as far as observations have gone on comets we have been able to detect nothing but the possibility of a spectrum of carbon, or of a compound of carbon.

Here again dimly and darkly the prism is pointing us to a possible connection between all the stars in heaven and all the comets and all the meteors which flit through the celestial spaces and fall upon our own earth.

I have already referred to the verdict of the prism in connection with the nebulæ, and there can be very little doubt, I think, that before the world is very much older the prism will also be perfectly competent to connect nebulæ with stars as it may possibly have already connected comets and meteors with them; but this point certainly is at present one of great difficulty, and it is a difficulty which no student of science will care to get out of, since in matters of this kind a difficulty is a matter of the highest importance, showing you as it does that part of the field of nature which requires most study.

I quite feel that this enormous subject, which modern science is opening up, is one the importance of which is so great and the interest in which is so general that I am sorry that the task of talking about it has not fallen upon the shoulders of one who is more competent to do it than I am. I hope, however, that feeble as my advocacy may have been, you are prepared to agree that the time will come when Celestial Chemistry, as investigated by means of the prism, will be acknowledged to be one of the most important branches of modern science.

J. NORMAN LOCKYER

SCIENTIFIC SERIALS

Journal of the Franklin Institute, February.—In this number Mr. Prindle has a paper (with numerous illustrations) On Recent Improvements in Construction of the Gunpowder Pile-driver.—A long and instructive paper by Mr. Loiseau, On Artificial Fuel, gives a *résumé* of what has hitherto been done in this direction; the author describing his own method, in which a mixture of 5 per cent. clay and 95 per cent. coal-dust, moistened with milk of lime, is moulded into oval lumps, which are then bathed in a waterproofing liquid (rosin dissolved in crude benzine) and dried. With 14 men only, a production of 150 tons per day can, it is said, be easily attained.—Prof. Houston announces the discovery of a new allotropic modification of phosphorus, obtained by boiling good phosphorus repeatedly in potassium hydrate (under certain conditions). This new modification retains for an indefinite time, apparently, the liquid state, even when exposed to temperatures considerably below the melting-point of ordinary phosphorus, from which it also differs in its non-oxidation on exposure to air, and, consequently, its not shining in the dark.—Mr. Chesebrough describes the construction of the Detroit River Tunnel; and Prof. Thurston has a note relative to the estimation of the chemical value of coals containing large quantities of ash.—Among the "Items and Novelties," it is stated that Prof. Thurston has gone very carefully into the subject of a scheme published by Mr. Chesebrough, for keeping canals open in winter by warming the water. The professor's calculations are given, and he finally arrives at an estimate of 5,412,500 dols. as the first cost of apparatus for a canal 350 miles long, 70 feet deep, in the latitude of Central New York; and 1,670,200 dols. for the maintenance per annum. He thinks the scheme deserving of investigation.

Astronomische Nachrichten, Nos. 1,976 and 1,977.—These numbers contain a paper by M. Lohse on the estimation of the depth of sun-spots, and at the same time to ascertain the influence of solar refraction. The principle of his method is as follows:—When a spot having its umbra concentric with penumbra, when seen from the vertical, is seen near the sun's limb, the umbra becomes excentric, and the depth of the umbra p' will be given by the formula $p' = \frac{\epsilon}{\cos\alpha}$ when ϵ is the excentricity and α the heliocentric position-angle of the spot from the axis, and assuming the spot steady, p' should remain constant as α and with it ϵ change. This, however, is found not to be the case, for p' gradually increases as the spot gets from the limb, showing it was raised by refraction at the limb, and therefore this change in the value of p' gives a measure of the sun's refraction. The same author also contributes a paper on the effect of the atmosphere of Venus in the transit over the sun, and he recommends the examination of its atmosphere with the spectroscope for absorption-bands.—J. Hortazzi gives the observations of transits for longitude of Nikolagew.—J. Palisa gives a large number of ring-micrometer observations on the minor planets and a few comets.—Dr. Holetschek gives the position of some seventy comparison-stars for planets and comets.—E. Stephan gives a list of ten new nebulæ discovered and observed at Marseilles; all seem excessively small. The elements of the new comet are given by Wilhelm as follows:—

$$\begin{aligned} T &= \text{March } 9{\cdot}8125 \text{ Berlin time.} \\ \Omega &= 48^\circ\ 17'\ 37''{\cdot}6 \\ \Pi &= 309^\circ\ 27'\ 46'' \\ i &= 52^\circ\ 29'\ 52''{\cdot}3 \\ \log. q &= 8{\cdot}591600 \end{aligned}$$

Memorie della Soc. degli Spectroscopisti Italiani, Oct. and Nov. 1873.—These numbers contain an interesting paper by P. Rosa, assistant at the Observatory at Rome, on the variability of the sun's diameter. He discusses the observations at Greenwich and other places from the year 1750 to 1870, during which time some 13,000 measurements of the solar diameter were made. From these observations he has constructed curves showing the variation of diameter, together with the variation in the number of spots. The agreement of these two curves is not very strong, but on his constructing secondary curves from every fourth year of these primary curves, beginning with any year, the resemblance becomes striking. There are also monthly curves given, showing the mean variation in diameter of the sun for each month, taking a mean of ten years for each curve. These show two maxima in March and September, and two minima in January and June. On examining the curve of variation in diameter, a marked minimum occurs about the year 1792. The author sets forth a theory to account for this variation, that since a comet, when at its perihelion, throws off large quantities of matter, so the sun when at its periastre may throw off matter and become reduced in size, and if such is the case its periastre happened in 1792.—G. Lorenzoni contributes papers on observations on the chromosphere, and on observing contacts in eclipses of the sun with the spectroscope.—G. de Lisa gives observations on solar spots in September, October, and November 1873, made at Palermo, giving a mean of about ten spots a day.—Prof. Young gives a note on the use of M. Rutherford's gratings in the place of prisms for the spectroscope.

SOCIETIES AND ACADEMIES

LONDON

Royal Society, March 19.—On the Attractions of Magnets and Electric Conductors, by George Gore, F.R.S.

Being desirous of ascertaining whether in the case of two parallel wires conveying electric currents the attractions and repulsions were between the currents themselves or the substances conveying them, and believing this question had not been previously settled, I made the following experiment:—

I passed a powerful voltaic current through the thick copper wire of a large electromagnet, and then divided it equally between two vertical pieces of thin platinum wire of equal diameter and length (about six or seven centimetres), so as to make them equally white hot, the two wires being attached to two horizontal cross wires of copper.

On approaching the two vertical wires symmetrically towards the vertical face of the one pole of the horizontally placed magnet, and at equal distances from it, so that the two downward currents in them might be equally acted upon by the downward and upward portions respectively of the currents which circulated round the magnet-pole, the one was strongly bent towards and the other from the pole, as was, of course, expected; but not the least sign of alteration of relative tempe-